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GLACIAL STUDIES IN GREENLAND. V.

THE REDCLIFF PENINSULA.

FROM the north side of the deep inlet formed jointly by Murchison Sound and Inglefield Gulf, McCormick Bay sets back to the northeast, while Bowdoin Bay, which lies to the east of it, sets back to the northwest. The result of these convergent courses is to bring the heads of the two bays near each other and to enclose a sub-triangular area whose three sides may be roughly taken as fifteen miles in length. Between the heads of the bays the ground is low and partially occupied by lakes which gives further emphasis to the peninsular character, for the most of the area is a plateau and this low tract has the moral effect of a partial disseverance. The margin of this plateau to a width varying from a few rods to perhaps three miles is bare of ice, except as glacial tongues intrude upon it. This portion reaches about 2000 feet in height. The central portion of the plateau is covered by an ice-cap, which, according to Lieutenant Peary, mounts up to 4000 or more feet in altitude. Whether this means that the ice is 2000 feet thick or that the land beneath the ice swells upward is a matter of uncertain interpretation. The configuration of the summit favors the view that the land participates in the increased elevation to some notable degree, but the ice is obviously thick. From this ice-cap tongues creep down into the valleys on all sides of the peninsula. They even descend to the northward upon the low neck connecting the peninsula with the mainland. Two of these ice-tongues on the south, two on the east, and one on the north were examined at hand. The others were only cursorily seen at greater or less distances.

Local ice-caps while almost immeasurably inferior to the inland *mer de glace* in general interest and significance are nevertheless in certain respects not only equal but even superior to it as factors in glacial study. They define more sharply the limitations of glacial accumulation. The occurrence of the border of the inland ice sheet at given elevations leaves us in doubt whether its presence signifies that the conditions of glaciation are there present normally, or whether the ice has simply been pushed forward to that point by the *mer de glace* back of it. Local ice-caps, on the other hand, show that the conditions of glaciation are unquestionably present. They thus enable us to determine quite accurately what elevations (under existing conditions) are adequate to produce glaciation, and to fix the limit of adequacy. So also, equal elevations being chosen as a basis of comparison, the local ice-caps furnish the means of estimating the relative influence of meteoric conditions.

The ice-cap of Redcliff peninsula is an excellent example of the plateau variety of the local type. It suffers no interruption from mountain peaks. It spreads in an unbroken sheet over the whole interior and creeps outwards in all direction. In this last feature it is felicitous in permitting, within so narrow limits, the study of glacial tongues moving toward all points of the compass.

The Fan glacier.—The most westerly of the tongues from the ice-cap of Redcliff peninsula has been designated the Fan glacier from the beautiful deployment of its lower portion.[1] It is but a lobe of the peninsular ice-cap descending a broad valley excavated in the shales and sandstones that constitute the uppermost division of the clastic series, which has been previously described. While no measurements were made, it will probably not be very far from the truth to regard its length as three miles and its breadth as falling little short of one mile. The glacier declines with a gentle and regular slope that imparts great beauty to its longitudinal profile (Fig. 23). This doubtless indicates much smoothness in the floor over which it is advancing, as well as freedom from lateral constrictions and topographic strains of all kinds. Its transverse profile, as seen from the valley in front is singularly symmetrical and graceful (Fig. 24). It is doubtful

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[1] A figure of this glacier is given by Professor Angelo Heilprin in Popular Science Monthly, November 1894, p. 12.

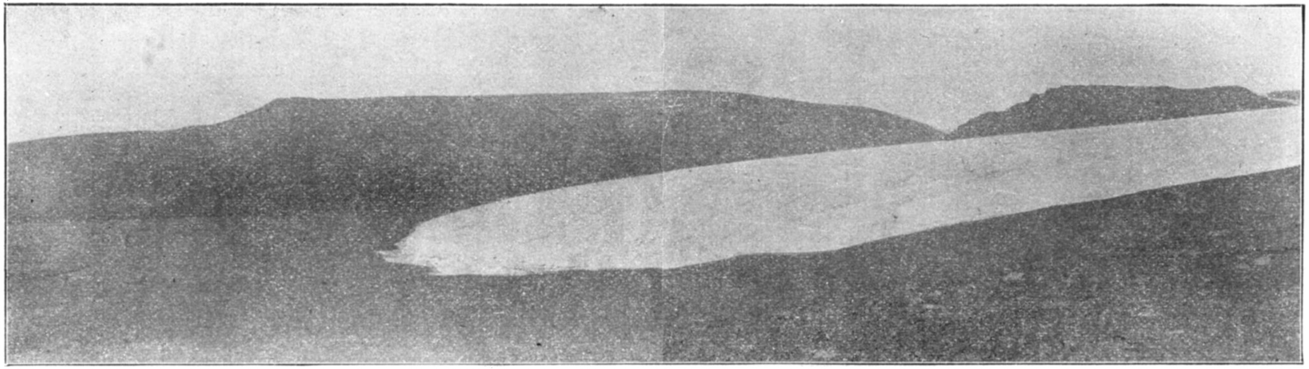

FIG. 23. Longitudinal profile of Fan glacier, from photograph by Professor William Libbey, Jr.

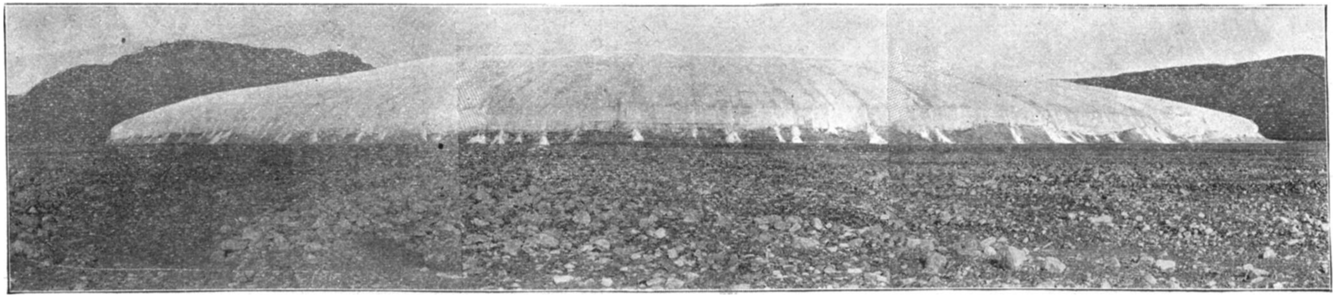

FIG. 24. Front view of Fan glacier, from photograph by Professor William Libbey, Jr.

whether any known glacier exceeds it in the beauty of its superficial curvatures. The foreground in the illustration shows that it is resting upon a plain formed by the deposits of its own waters, and to this its symmetry is doubtless chiefly due. It may be taken as a rare type of the behavior of ice in an exceptionally untrammeled situation under the conditions of a high northern latitude. The photographic illustrations express for themselves the angle of the slope and the law of the profile's curvature.

Next to its graceful contours the steep front invites attention. It will be observed in the figures (Figs. 23, 24, 25, 26 and 27) that at the base there is an embankment, presently to be described, above which the ice rises nearly vertically to a height about seventy-five feet above the plain. Above this there is an arching but receding brow, the curvature of which becomes more and more gentle as it retires from the face. It will be seen that the verticality of the.face maintains itself throughout all its arching course across the valley, and that it is as pronounced in the center as at the sides. The verticality is obviously due neither to lateral nor to central agencies as such. It cannot be attributed merely to the reflection of rays from surrounding elevations, for there are none opposite its wide frontage. The gravel plain spreads uninterruptedly down to the gulf. It will not be wise to draw conclusions respecting the cause of this verticality of face at this point, as we shall have occasion to note the phenomenon in much more pronounced forms in a dozen or more glaciers which present various attitudes and diverse environments.

Along the base of the glacial front it will be observed that there are numerous white cones (Figs. 24, 26 and 27), and between these a sloping embankment resting against the steep face of the glacier. Rising from each of the white cones there may be seen lines which reach back across the brow of the glacier and are lost upon its upper surface. These are little channel-ways cut by streamlets formed on the surface of the glacier by its melting. As these streamlets coursed rapidly down their little channels they dislodged coarse granules of the ice, loosened by the sun, and carried them away and, precipitating them over the face

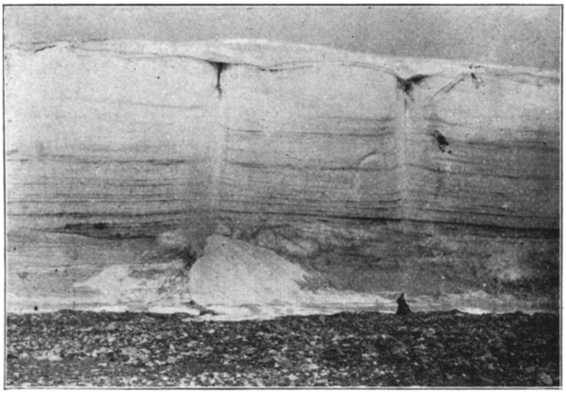

FIG. 25, Face of Fan glacier. Photo. by Prof. Wm. Libbey, Jr.

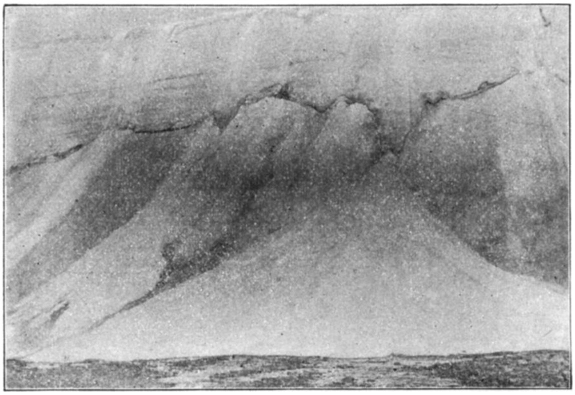

FIG. 26. Cones in front of Fan glacier. Photo. by Prof. Wm. Libbey, Jr.

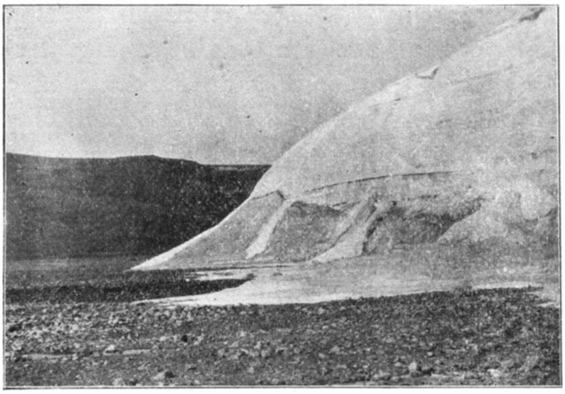

FIG. 27. Terminal profile and cones of Fan glacier. Photo. by Prof. Libbey, Jr.

of the glacier, heaped them up in cones at its base. Not only was this indicated by the structure of the cones themselves, but the process of their formation was observed in actual progress.[1] Its rapidity was something surprising. As the granules were brought down the ice-wall by the cascading rivulet they occasionally struck projections and bounded forth into the air and fell upon the slopes of the cone. In other cases they were seen to leap forth from the rivulet when it struck the summit of the cone ; but in the main they simply gathered at the apex of the cone until they blocked up the little channel-way and forced the rivulet to seek another course only to be blocked in turn and thus forced to and fro, building up the cone symmetrically. The rapidity of action observed was doubtless somewhat exceptional for the day was unusually bright and warm. It is doubtful whether it was equaled by more than ten days during the entire season.

The embankment between the cones had a well developed granular structure, but it appeared to be formed in considerable part from wind-drift accumulations. It was very notably solidified into a half-ice. The surface was covered with dirt and to some extent with rocky and earthy débris that had fallen from the face of the glacier. From its solidity, dirtiness and other features it seemed scarcely possible that it was the product of the current season solely. As may be inferred from the illustrations, it lay close against the front of the ice-wall rising in some places half its height. Nowhere did I observe any disruption or crumpling of the embankment as though the glacier had crowded against it since it was formed, nor, on the other hand, it is scarcely needful to say, was there any crevasse or interval between it and the glacier, indicating a retreat of the ice. Such retreat would only be produced by the melting of the glacier backward faster than it moved on, and such melting could scarcely be supposed to take place without involving the destruction of the embankment as a concurrent, if not a prerequisite, condition. Manifestly melting could not have counteracted the onward movement at the base of the glacier because of the protection interposed by the embankment itself. It is obvious that this phenomenon suggests, if it does not demonstrate, the inertness of the glacier at its extremity. It is difficult to see how it could be moving at any appreciable rate at its end without some disruption of the embankment, unless it be supposed that the embankment was pushed bodily forward as though a part of the glacier itself. In this case there would be reason to expect disruptive phenomena at the forward edge of the embankment, none of which was observed.

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[1] PROFESSOR LIBBEY was the first to note the action in progress.

The existence of the numerous streamlets on the surface of the glacier and their size, indicating that they had run considerable courses, is an index of the freedom of the lower part of the glacier from crevasses. This freedom is in signal harmony with the smoothness of its bottom and the slowness of its motion. It is interesting in this connection to note especially that it is not longitudinally crevassed, as is the Rhone glacier, which fans out at its foot in a somewhat analogous, but far less beautiful fashion.

Though not the most obtrusive, perhaps the most important feature displayed by the glacier was its stratification. Standing before its face at any point, it might be seen to be formed of definite layers and even of laminations. The photographic illustrations exhibit this in some measure, but the variation in light between the alternations of the more solid and the more porous ice was too delicate to be fully caught by the camera. The simplest form of the stratification consisted of alternations of porous, opaque white layers with solid translucent blue ones. The blue sheets were thin, while the white ones were relatively thick. The more conspicuous variety of stratification was formed by the introduction of rock rubbish between layers of relatively pure ice (Fig. 25). In the Fan glacier, this reached a far less notable development than in the glaciers which will hereafter claim our attention. But even there it was sufficiently pronounced to be a very notable feature. It is important to observe that the rocky material was distributed in definite horizons between the ice layers. It was not promiscuously scattered through the ice. The débris varied in coarseness from bowlders of large dimensions downward to fine silt. The coarse and fine material were not separated. It was not a phenomenon of assortment. Coarse and fine were arranged along the same horizons. The layers or laminæ of ice which were close together where only silt and sand were present separated so far as needful to admit bowlders. It was interesting to observe that the laminæ as they approached a bowlder parted, a portion curving over the bowlder and a portion curving under it. No good photographic illustrations of this were secured from this glacier, but fair ones from other glaciers will be given later. Many of these other glaciers show the phenomena of stratification and the inclusion of débris so much more clearly and pronouncedly that we may leave further details to be subsequently described.

The débris was enclosed almost exclusively in the basal beds, the upper portion of the glacier being almost entirely free from rocky material. The distribution throughout the lower layers was not strictly progressive from the base upwards. Higher layers sometimes contained more than lower ones, but the general fact of basal distribution was very pronounced. It was further observed that there was more débris in the layers near the sides of the glaciers than in the central portion. This is expressive of a law which somewhat widely obtains.

The top of the glacier was not reached by us, but from what could be seen it appeared to be essentially free from bowldery erratics, though somewhat discolored by atmospheric dust.

The débris which was embedded in the Fan glacier was largely composed of a hard pinkish sandstone derived from the middle member of the clastic series previously described. There was present, however, a considerable sprinkling of crystalline bowlders of the granitic type and occasionally bowlders of the greenstone type. If it is recalled that the source of this ice-flow was probably not more distant than the middle of the peninsula, the stratigraphy beneath the glacier is readily inferred. The uppermost member of the clastic series which occurs in the sides of the valley adjacent to the lower part of the glacier must soon be replaced at the surface by the rising of the pink sandstone from beneath it. This in turn must soon be replaced by the crystalline terrane, which apparently constitutes the nucleus of the peninsula; indeed the crystalline terrane was afterwards observed to come out to the edge of the peninsula on its east side facing Bowdoin Bay. The material in the base of the glacier must apparently have been picked up from the rocky surface beneath the ice-cap. The derivation was apparently basal. Some part of it, however, may have been introduced laterally as it descended from the plateau into the valley. This seems to be indicated by the fact that the sides of the glacier contained somewhat more débris then the central portion.

The material in the ice was somewhat rubbed and scratched but not markedly so. Indeed the first impression was that of unsubdued angularity, but observation showed that some abrasion had been suffered by a considerable percentage of the blocks included. Well rounded and thoroughly striated bowlders were rare, though present. This, however, was scarcely typical. Similar material in other glaciers observed was notably bruised and scratched. Very likely the angularity in this instance is an effect of the open, free course which this glacier enjoyed in its relatively broad, straight valley.

At the edge of the ice, the embedded débris was being freed by melting and was dropping in front. The amount of débris in the ice being scant, the accumulation was small. There was an almost complete absence of any terminal moraine in front of the glacier. This will be seen by consulting the photographic illustrations. If any terminal ridge had been formed, it was either concealed beneath the margin of the glacier or by the frontal embankment above described. The latter could not have afforded a general concealment because its continuity was not complete. At some points the smooth gravel plain of the valley below could be traced up to the actual front of the ice. Nor was there any notable moraine along the sides of the glacier. As in the case of the Igloodahomyne glacier the drainage was chiefly accomplished by a stream on each side occupying a trench between it and the valley sides. Sometimes the lateral stream tunneled under a portion of the ice, leaving a bridge arching over it from the body of the glacier to the side of the valley. In other cases the stream cut across the edge of the glacier dissevering a portion of it. These were cases in which the wash from the slope of the adjacent highlands was very considerable and encroached upon the glacier, burying the part that became dissevered. It was interesting to observe that much of this buried ice was exceptionally pure and solid. In other portions, however, it contained interstratified débris, and at some points there were irregular impregnations of rocky material.

On the east side there was a very significant phenomenon displayed in connection with an embossment or buried spur of rock (Fig. 28). The lateral stream of the glacier crossed the neck of rock connecting this with the valley side, cascading over it and cutting a channel in it. Next to the glacier the rock rose somewhat and was covered at the foot of the ice-wall which formed the side of the glacier by a talus derived from the lower layers of the ice. If reference is made to Figs. 28, 29, and 30 much unsatisfactory description may be avoided. It will be observed that near the base of the glacier there is a dark belt which consists largely of stony débris held in the matrix of ice. Below this, not well shown in the figure, there is ice less freely charged with rocky matter. Above this it will be seen that there are at intervals several dark lines, which are simply rock rubbish sandwiched between layers of ice. The notable feature is the curve which these assume. At the right, or up-stream end, the layers rise by beautiful curves which gradually flatten as they pass over the embossment. Beyond the summit they descend, gently at first, but more rapidly later. When they have reached a point some distance below the embossment, they bend backwards to varying extents and with various degrees of abruptness. The curvature is least abrupt near the embossment and increases generally with distance. The recurved portion nearest the embossment is short and its lower end soon becomes obscured by the fallen débris. The higher layers return farther

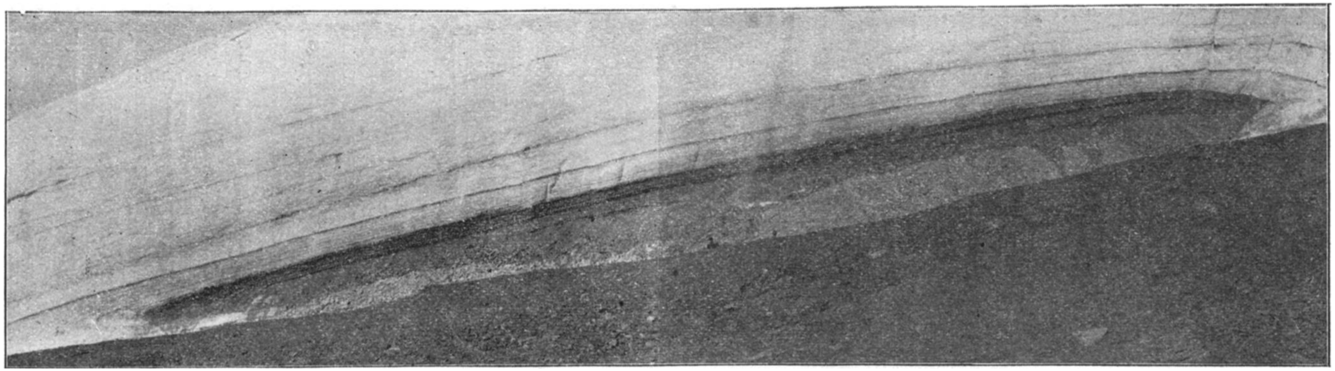

FIG. 29. Curving of laminæ, east side of Fanglacier. Photograph by Prof. Libbey.

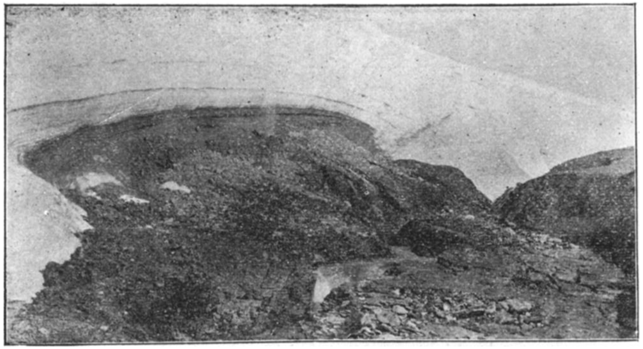

FIG. 28. General view of laminæ curving over embossment of rock and drift. Photograph by Prof. Libbey.

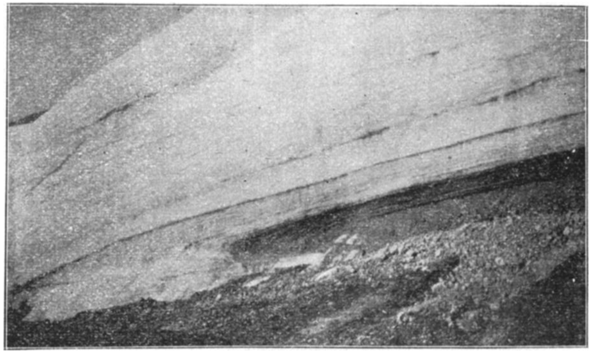

FIG. 30. Recurving laminæ below embossment, east side Fan glacier.

and the one several feet above the broad dark band after curving sharply about runs several rods backwards before it is lost from sight under the sloping débris. (See Figs. 29 and 30.)

The drumloidal[1] nature of the curve described by these layers is very suggestive, and it is perhaps not too much to believe that the essential principles of drumlin formation are here expressed. It will be wise, perhaps, to defer inferences and special discussions until other phenomena of like nature are described and a broader basis for induction is laid.

T. C. CHAMBERLIN.

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[1] I suppose that drumlinoidal is the rigidly correct adjective to use here, but as drumloidal is briefer and better in itself, it seems preferable to be governed by the euphonies and utilities of language than by the stiff formulas of a conventional grammar.